Atomic-scale imaging reveals the shape and size of a technologically interesting magnetic quasiparticle.
scope (STM) tip. Like all STM techniques, this method measures the quantum-mechanical current that tunnels from a surface to the probe tip. In this case, the current depends on the angle between a spin on the probe tip and the spin on the surface, so the technique can map the orientation of spins at each point on the surface. Similarly, the current from the tip is spin polarized and can be used to exert a torque on the spins in the magnet to either create or annihilate a skyrmion.

In their new work, Romming et al. use the same technique to image the internal structure of a skyrmion in the PdFe bilayer, and its response to an applied magnetic field. The skyrmion can be thought of as a tiny, 2D bubble-like region whose magnetization points in the opposite direction to the surrounding material. Its core can be considered truly pointlike. But the skyrmion has to have a finite size because it takes a short distance (in this case about 2 nanometers) for the magnetization to twist back to the background direction. Applying a magnetic field in the opposite direction to the skyrmion core magnetization compresses the bubble (Fig. 1), changing its shape. Using the STM, Romming et al. mapped the skyrmion’s shape versus magnetic field as the bubble was compressed to approximately half its equilibrium size. Their results fit the existing theory [1], thus confirming it. These fits also allowed the researchers to determine the values of $J$ and $D$ in their material. These values, which are difficult to measure in other ways, determine the skyrmion’s size, and researchers will need to know them for any technology that makes uses of skyrmions.

The physics of skyrmions is fascinating because of their special topological properties [4]. From a technological perspective, skyrmion-based devices have the potential to store and process information at unprecedentedly small sizes and levels of energy consumption. For example, the presence/absence of the skyrmion could serve as the 0 and 1 in a data bit in a racetrack memory [6]. The work of Romming et al. shows that existing theories provide a sound basis for the micromagnetic design of such devices. This is a remarkable thing in itself, since these theories are continuum models, yet the new work shows they remain valid at atomic length scales. Moreover, the results show skyrmions are robust: they can withstand a reverse field of almost 3 teslas. So far, magnetic skyrmions have only been observed at low temperatures. (Romming et al. performed their experiments at 4.2 K.) But very recently, researchers have observed skyrmions in a room-temperature magnet, making their promise for future technologies more realistic [10].

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References


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Christopher Marrows is Professor of Condensed Matter Physics at the University of Leeds. He received his Ph.D. from the University of Leeds in 1997, where he was a Research Fellow of the Royal Commission for the Exhibition of 1851 at the same institution from 1998 to 2000. He is a Fellow of the Institute of Physics and a Senior Member of the IEEE. He gave the 2011 Wohlfarth Lecture in recognition of his work on nanomagnetism. His current research interests include many aspects of nanomagnetism and spintronics, with the general theme of emergent properties of condensed-matter systems, including emergent quasiparticles such as magnetic monopoles and skyrmions.